



# Wideband Voltage Feedback Amplifier

## AD9622\*

### FEATURES

**220 MHz Small Signal Bandwidth**  
**160 MHz Large Signal BW (4 V p-p)**  
**High Slew Rate: 1500 V/ $\mu$ s**  
**Low Distortion: -66 dB @ 20 MHz**  
**Fast Settling: 14 ns to 0.01%**  
**3.5 nV/ $\sqrt{\text{Hz}}$  Spectral Noise Density**  
 **$\pm 3$  V Supply Operation**

### APPLICATIONS

**ADC Input Signal Amplifier**  
**Differential Amplifiers**  
**IF/RF Amplifiers**  
**Pulse Amplifiers**  
**Professional Video**  
**DAC Current-to-Voltage**  
**Baseband and Video Communications**  
**Active Filters/Integrators/Log Amps**

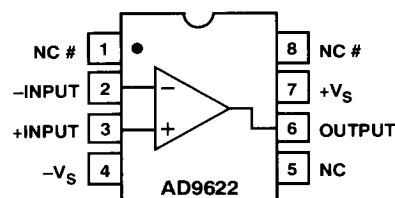
### GENERAL DESCRIPTION

The AD9622 is one of a family of very high speed and wide bandwidth amplifiers utilizing a voltage feedback architecture. These amplifiers define a new level of performance for voltage feedback amplifiers, especially in the categories of large signal bandwidth, slew rate, settling, low distortion, and low noise.

Proprietary design architectures have resulted in an amplifier family that combines the most attractive attributes of both current feedback and voltage feedback amplifiers. The AD9622 exhibits extraordinarily accurate and fast pulse response characteristics (8 ns settling to 0.1%) as well as extremely wide small and large signal bandwidth previously found only in current feedback amplifiers. When combined with balanced high impedance inputs and low input noise more common to voltage feedback architectures, the AD9622 offers performance not previously available in a monolithic operational amplifier.

\*Protected by U.S. Patent 5,150,074 and others pending.

### CONNECTION DIAGRAM



# OPTIONAL CAPACITOR CB CONNECTED HERE DECREASES SETTLING TIME (SEE TEXT).

Other members of the AD962X amplifier family are the AD9621 ( $G = +1$ ), AD9623 ( $G = +4$ ), and the AD9624 ( $G = +6$ ). A separate data sheet is available from Analog Devices for each model. Each generic device has been designed for a different minimum stable gain setting, allowing users flexibility in optimizing system performance. Dynamic performance specifications such as slew rate, settling time, and distortion vary from model to model. The table below summarizes key performance attributes for the AD962X family and can be used as a selection guide.

The AD9622 is offered in industrial and military temperature ranges. Industrial versions are available in plastic DIP, SOIC, and cerdip; MIL versions are packaged in cerdips.

### PRODUCT HIGHLIGHTS

1. Wide Large Signal Bandwidth
2. High Slew Rate
3. Fast Settling
4. Low Distortion
5. Output Short-Circuit Protected
6. Low Intermodulation Distortion of High Frequencies

| Parameter                        | AD9621 | AD9622 | AD9623 | AD9624 | Units       |
|----------------------------------|--------|--------|--------|--------|-------------|
| Minimum Stable Gain              | +1     | +2     | +4     | +6     | V/V         |
| Harmonic Distortion (20 MHz)     | -52    | -66    | -64    | -66    | dB          |
| Large Signal Bandwidth (4 V p-p) | 130    | 160    | 190    | 200    | MHz         |
| SSBW (0.5 V p-p)                 | 350    | 220    | 270    | 300    | MHz         |
| Slew Rate                        | 1200   | 1500   | 2100   | 2200   | V/ $\mu$ s  |
| Rise/Fall Time (0.5 V Step)      | 2.4    | 1.7    | 1.6    | 1.5    | ns          |
| Settling Time (to 0.1%/0.01%)    | 7/11   | 8/14   | 8/14   | 8/14   | ns          |
| Input Noise (0.1 MHz-200 MHz)    | 80     | 49     | 36     | 32     | $\mu$ V rms |

### REV. 0

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# AD9622—SPECIFICATIONS

## DC ELECTRICAL CHARACTERISTICS (Unless otherwise noted, $\pm V_S = \pm 5\text{ V}$ ; $R_{LOAD} = 100\ \Omega$ ; $A_V = 2$ ; $R_F = 270\ \Omega$ )

| Parameter                                         | Conditions                    | Temp  | Test Level | AD9622AN/AQ/AR |       |     | AD9622SQ |       |     | Units  |
|---------------------------------------------------|-------------------------------|-------|------------|----------------|-------|-----|----------|-------|-----|--------|
|                                                   |                               |       |            | Min            | Typ   | Max | Min      | Typ   | Max |        |
| DC SPECIFICATIONS <sup>1</sup>                    |                               |       |            |                |       |     |          |       |     |        |
| Input Offset Voltage                              |                               | +25°C | I          | −10            | ±2    | +10 | −10      | ±2    | +10 | mV     |
|                                                   |                               | Full  | VI         | −12            |       | +12 | −12      |       | +12 | mV     |
| Input Bias Current                                |                               | +25°C | I          |                | 7     | 14  |          | 7     | 14  | μA     |
|                                                   |                               | Full  | VI         |                |       | 18  |          |       | 18  | μA     |
| Bias Current TC                                   |                               | Full  | V          |                | 35    |     |          | 35    |     | nA/°C  |
| Input Offset Current                              |                               | +25°C | I          | −2             | ±0.3  | +2  | −2       | ±0.3  | +2  | μA     |
|                                                   |                               | Full  | VI         | −3             |       | +3  | −3       |       | +3  | μA     |
| Offset Current TC                                 |                               | Full  | V          |                | 2.5   |     |          | 2.5   |     | nA/°C  |
| Input Resistance                                  |                               | +25°C | V          |                | 500   |     |          | 500   |     | kΩ     |
| Input Capacitance                                 |                               | +25°C | V          |                | 1.2   |     |          | 1.2   |     | pF     |
| Common-Mode Range                                 |                               | Full  | VI         | ±3.0           | ±3.4  |     | ±3.0     | ±3.4  |     | V      |
| Common-Mode Rejection Ratio                       | ΔV <sub>CM</sub> = 1 V        | +25°C | I          | 47             | 57    |     | 47       | 57    |     | dB     |
| Open-Loop Gain                                    | V <sub>OUT</sub> = ±2 V p-p   | +25°C | V          |                | 60    |     |          | 60    |     | dB     |
| Output Voltage Range                              |                               | Full  | VI         | ±3.0           | ±3.4  |     | ±3.0     | ±3.4  |     | V      |
| Output Current                                    |                               | Full  | VI         | 60             | 70    |     | 60       | 70    |     | mA     |
| Output Resistance                                 |                               | +25°C | V          |                | 0.3   |     |          | 0.3   |     | Ω      |
| FREQUENCY DOMAIN                                  |                               |       |            |                |       |     |          |       |     |        |
| Bandwidth (−3 dB)                                 |                               |       |            |                |       |     |          |       |     |        |
| Small Signal                                      | V <sub>OUT</sub> ≤ 0.4 V p-p  | Full  | II         | 160            | 220   |     | 160      | 220   |     | MHz    |
| Large Signal <sup>2</sup>                         | V <sub>OUT</sub> = 4 V p-p    | +25°C | V          |                | 160   |     |          | 160   |     | MHz    |
| Amplitude of Peaking                              | Full Spectrum                 | Full  | II         |                | 0.2   | 1.2 |          | 0.2   | 1.2 | dB     |
| Amplitude of Roll-off                             | DC to 100 MHz                 | Full  | II         |                | 0     | 0.8 |          | 0     | 0.8 | dB     |
| Phase Nonlinearity                                | 0.3 MHz to 100 MHz            | +25°C | V          |                | 1.3   |     |          | 1.3   |     | degree |
| 2nd Harmonic Distortion                           | 2 V p-p; 20 MHz               | Full  | II         |                | −66   | −56 |          | −66   | −56 | dBc    |
| 3rd Harmonic Distortion                           | 2 V p-p; 20 MHz               | Full  | II         |                | −68   | −56 |          | −68   | −56 | dBc    |
| Common-Mode Rejection Ratio                       | @ 20 MHz                      | +25°C | V          |                | +23   |     |          | +23   |     | dB     |
| Spectral Input Noise Voltage                      | 1 MHz to 200 MHz              | +25°C | V          |                | 3.5   |     |          | 3.5   |     | nV/√Hz |
| Spectral Input Noise Current                      | 1 MHz to 200 MHz              | +25°C | V          |                | 3.2   |     |          | 3.2   |     | pA/√Hz |
| Average Equivalent Integrated Input Noise Voltage | 0.1 MHz to 200 MHz            | +25°C | V          |                | 49    |     |          | 49    |     | μV rms |
| TIME DOMAIN                                       |                               |       |            |                |       |     |          |       |     |        |
| Slew Rate                                         | V <sub>OUT</sub> = 5 V Step   | Full  | IV         | 1150           | 1500  |     | 1150     | 1500  |     | V/μs   |
| Rise/Fall Time                                    | V <sub>OUT</sub> = 0.5 V Step | +25°C | V          |                | 1.7   |     |          | 1.7   |     | ns     |
|                                                   | V <sub>OUT</sub> = 5 V Step   | Full  | IV         |                | 3.1   | 4.2 |          | 3.1   | 4.2 | ns     |
| Overshoot                                         | V <sub>OUT</sub> = 2 V Step   | Full  | IV         |                | 3     | 15  |          | 3     | 15  | %      |
| Settling Time                                     |                               |       |            |                |       |     |          |       |     |        |
| To 0.1%                                           | V <sub>OUT</sub> = 2 V Step   | +25°C | V          |                | 8     |     |          | 8     |     | ns     |
| To 0.01%                                          | V <sub>OUT</sub> = 2 V Step   | Full  | IV         |                | 14    | 19  |          | 14    | 19  | ns     |
| To 0.1% <sup>3</sup>                              | V <sub>OUT</sub> = 4 V Step   | +25°C | V          |                | 10    |     |          | 10    |     | ns     |
| To 0.01% <sup>3</sup>                             | V <sub>OUT</sub> = 4 V Step   | +25°C | V          |                | 17    |     |          | 17    |     | ns     |
| Overdrive Recovery                                | 2× to ±2 mV                   | +25°C | V          |                | 150   |     |          | 150   |     | ns     |
| Differential Gain (4.3 MHz)                       | R <sub>L</sub> = 150 Ω        | +25°C | V          |                | 0.01  |     |          | 0.01  |     | %      |
| Differential Phase (4.3 MHz)                      | R <sub>L</sub> = 150 Ω        | +25°C | V          |                | <0.01 |     |          | <0.01 |     | degree |
| POWER SUPPLY REQUIREMENTS <sup>1</sup>            |                               |       |            |                |       |     |          |       |     |        |
| Supply Voltage (±V <sub>S</sub> )                 |                               | Full  | IV         | 3.0            | 5.0   | 5.5 | 3.0      | 5.0   | 5.5 | V      |
| Quiescent Current                                 |                               |       |            |                |       |     |          |       |     |        |
| +I <sub>S</sub>                                   | +V <sub>S</sub> = 5 V         | Full  | VI         |                | 23    | 29  |          | 23    | 29  | mA     |
| −I <sub>S</sub>                                   | −V <sub>S</sub> = −5 V        | Full  | VI         |                | 23    | 29  |          | 23    | 29  | mA     |
| Power Supply Rejection Ratio                      | ΔV <sub>S</sub> = 0.5 V       | +25°C | I          | 54             | 63    |     | 54       | 63    |     | dB     |

### NOTES

<sup>1</sup>Measured at  $A_V = 21$ .

<sup>2</sup>Effective large signal bandwidth; the device should not be stressed above  $250\text{ V} \times \text{MHz}$  ( $V_{OUT}\text{ p-p} \times \text{Frequency}$ ) to ensure long term reliability.

<sup>3</sup>Measured with a  $0.001\ \mu\text{F}$  CB capacitor connected across Pins 1 and 8.

Specifications subject to change without notice.

**ABSOLUTE MAXIMUM RATINGS<sup>1</sup>**

|                                                    |                                             |
|----------------------------------------------------|---------------------------------------------|
| Supply Voltages ( $\pm V_S$ )                      | $\pm 6$ V                                   |
| Common-Mode Input Voltage                          | $\pm V_S$                                   |
| Voltage Swing $\times$ Bandwidth Product           | $250 \text{ V} \times \text{MHz}$           |
| Differential Input Voltage                         | 6 V                                         |
| Continuous Output Current <sup>2</sup>             | 90 mA                                       |
| <b>Operating Temperature Ranges</b>                |                                             |
| AN, AQ, AR                                         | $-40^\circ\text{C}$ to $+85^\circ\text{C}$  |
| SQ                                                 | $-55^\circ\text{C}$ to $+125^\circ\text{C}$ |
| <b>Storage Temperature</b>                         |                                             |
| Ceramic                                            | $-65^\circ\text{C}$ to $+150^\circ\text{C}$ |
| Plastic                                            | $-65^\circ\text{C}$ to $+125^\circ\text{C}$ |
| <b>Junction Temperature</b>                        |                                             |
| Ceramic <sup>3</sup>                               | $+175^\circ\text{C}$                        |
| Plastic <sup>3</sup>                               | $+150^\circ\text{C}$                        |
| Lead Soldering Temperature (1 minute) <sup>4</sup> | $+220^\circ\text{C}$                        |

**NOTES**

<sup>1</sup>Absolute maximum ratings are limiting values to be applied individually, and beyond which the serviceability of the circuit may be impaired. Functional operability is not necessarily implied. Exposure to absolute maximum rating conditions for an extended period of time may affect device reliability.

<sup>2</sup>Output is short-circuit protected; for maximum reliability, 90 mA continuous current should not be exceeded.

<sup>3</sup>Typical thermal impedances (part soldered onto board; no air flow):

Ceramic DIP:  $\theta_{JA} = 100^\circ\text{C/W}$ ;  $\theta_{JC} = 30^\circ\text{C/W}$

Plastic SOIC:  $\theta_{JA} = 125^\circ\text{C/W}$ ;  $\theta_{JC} = 45^\circ\text{C/W}$

Plastic DIP:  $\theta_{JA} = 90^\circ\text{C/W}$ ;  $\theta_{JC} = 45^\circ\text{C/W}$

<sup>4</sup>Temperature shown is for surface mount devices, mounted by vapor phase soldering. Through-hole devices (Ceramic and Plastic DIPs) can be soldered at  $+300^\circ\text{C}$  for 10 seconds.

**ORDERING GUIDE**

| Model    | Temperature Range                           | Package Description | Package Option |
|----------|---------------------------------------------|---------------------|----------------|
| AD9622AN | $-40^\circ\text{C}$ to $+85^\circ\text{C}$  | 8-Pin Plastic DIP   | N-8            |
| AD9622AQ | $-40^\circ\text{C}$ to $+85^\circ\text{C}$  | 8-Pin Cerdip        | Q-8            |
| AD9622AR | $-40^\circ\text{C}$ to $+85^\circ\text{C}$  | 8-Pin SOIC          | R-8            |
| AD9622SQ | $-55^\circ\text{C}$ to $+125^\circ\text{C}$ | 8-Pin Cerdip        | Q-8            |

**EXPLANATION OF TEST LEVELS****Test Level**

I – 100% production tested.

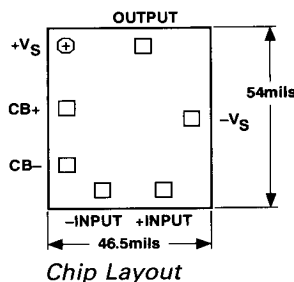
II – 100% production tested at  $+25^\circ\text{C}$ , and sample tested at specified temperatures. AC testing of “A” grade devices done on sample basis.

III– Sample tested only.

IV– Parameter is guaranteed by design and characterization testing.

V – Parameter is a typical value only.

VI– All devices are 100% production tested at  $+25^\circ\text{C}$ . 100% production tested at temperature extremes for extended temperature devices; sample tested at temperature extremes for commercial/industrial devices.

**THEORY OF OPERATION**

The AD9622 is a wide bandwidth voltage feedback amplifier that is guaranteed for minimum gain stability of +2. Since its open loop frequency response follows the conventional 6 dB/octave roll-off, its gain bandwidth product is basically constant. Increasing its closed-loop gain results in a corresponding decrease in small signal bandwidth. The AD9622 typically maintains a 60 degree unity loop gain phase margin with  $R_F \approx 270 \Omega$ . This high margin minimizes the effects of signal and noise peaking.

**Feedback Resistor Choice**

At minimum stable gain (+2), the AD9622 provides optimum dynamic performance with  $R_F = 270 \Omega$ . When using this value and following the high speed layout guidelines, a shunt capacitor ( $C_F$ ) should not be required. This value for  $R_F$  provides the best combination of wide bandwidth, low peaking, and distortion.

However, if improved gain flatness is desired, a shunt capacitor ( $C_F$ ) will provide extra phase margin. This reduces both overshoot and peaking with only a slight reduction of bandwidth.

As an example, if the amplifier exhibits (worst case) peaking of 1 dB with  $R_G \parallel R_F = 135 \Omega$  ( $A_V = 2$ ), then using a  $C_F$  of  $\approx 1.5 \text{ pF}$  across  $R_F$  will reduce this peaking to 0 dB. In addition, overshoot, noise, and settling time (0.01%) will also improve. This comes at the expense of slightly decreased closed-loop bandwidth due to the  $R_F \times C_F$  time constant created.

If the equivalent input capacitance greatly exceeds 2 pF (due to source drive or long input traces to the amplifier), then added shunt capacitance ( $C_F$ ) will be necessary to maintain stability.

Likewise, if larger  $R_G/R_F$  minimum-gain setting resistors are used,  $C_F$  will be necessary. As a rule of thumb, if the product of  $R_F \parallel R_G \times C_I \leq 270 \times 10^{-12}$  seconds, then  $C_F$  is not required (for maximum bandwidth applications) and the amplifier's phase margin will maintain about  $60^\circ$ .

For  $R_F \parallel R_G > 150 \Omega$ , use a  $C_F$  equal to  $C_I \times R_G/R_F$ . As the value of  $R_F \parallel R_G$  increases, the bandwidth of the amplifier will begin to be controlled by the  $R_F \times C_F$  time constant. Increasing  $C_F$  much beyond these guidelines will also cause amplifier instability.

**Pulse Response**

Unlike a traditional voltage feedback amplifier in which slew speed is usually dictated by its front end dc quiescent current and gain bandwidth product, the AD9622 provides “on demand” transconductance current that increases proportionally to the input “step” signal amplitude. This results in slew speeds (1500 V/ $\mu\text{s}$ ) comparable to wideband current feedback designs. This, combined with relatively low input noise current (3.2 pA/ $\sqrt{\text{Hz}}$ ), gives the AD9622 the best attributes of both voltage and current feedback amplifiers.

**Bootstrap Capacitor ( $C_B$ )**

In most applications, the  $C_B$  capacitor should not be required. Under certain conditions, it can be used to further enhance settling time performance.

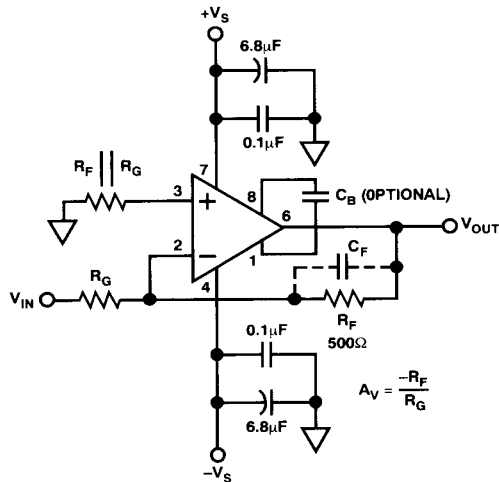


Figure 1. Inverting Gain Connection Diagram

The  $C_B$  capacitor (0.001  $\mu\text{F}$ ) connects to the internal high impedance nodes of the amplifier. Using this capacitor will reduce the large signal (4 V) step output settling time by 3 ns to 5 ns for 0.05% or greater accuracy. For settling accuracy less than 0.05% or for smaller step sizes, its effect will be less apparent.

Under heavy slew conditions, this capacitor forces the internal signal (initial step) amplitude to be controlled by the “on” (slewed) transistor, preventing its complement from completely turning off. This allows for faster settling time of these internal nodes and also the output.

In the frequency domain, total (high frequency) distortion will be approximately the same with or without  $C_B$ . Typically, the 3rd harmonic will be greater than the 2nd without  $C_B$ . This will be reversed with  $C_B$  in place.

## APPLICATIONS

The AD9622 is a voltage feedback amplifier and is well suited for such applications as active filters, and log amplifiers. The device’s wide bandwidth (230 MHz), phase margin ( $55^\circ$ ), low noise current (3.2 pA  $/\sqrt{\text{Hz}}$ ), and slew rate (1500 V/ $\mu\text{s}$ ) give higher performance capabilities to these applications over previous voltage feedback designs.

With a settling time of 15 ns to 0.01% and 8 ns to 0.1%, the device is an excellent choice for DAC I/V conversion. The same characteristics along with low harmonic distortion make it a good choice for ADC buffering/amplification. With its superb linearity at relatively high signal frequencies, it is an ideal driver for ADCs up to 14 bits.

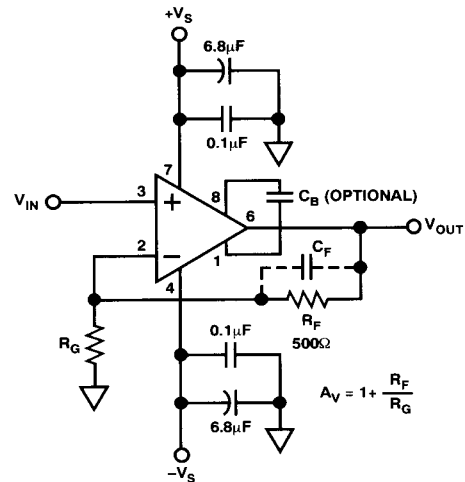


Figure 2. Noninverting Gain Connection Diagram

## Layout Considerations

As with all wide bandwidth components, printed circuit layout is critical to obtain best dynamic performance with the AD9622. The ground plane in the area of the amplifier and its associated components should cover as much of the component side of the board as possible (or first interior layer of a multilayer surface mount board).

The ground plane should be removed in the area of the inputs and  $R_F$  and  $R_G$  to minimize stray capacitance at the input. The same precaution should be used for  $C_B$ , if used. Each power supply trace should be decoupled close to the package with a 0.1  $\mu\text{F}$  ceramic capacitor, plus a 6.8  $\mu\text{F}$  tantalum nearby.

All lead lengths for input, output, and feedback resistor should be kept as short as possible. All gain setting resistors should be chosen for low values of parasitic capacitance and inductance, i.e., microwave resistors and/or carbon resistors.

Microstrip techniques should be used for lead lengths in excess of one inch. Sockets should be avoided if at all possible because of their high series inductance. If sockets are necessary, individual pin sockets such as AMP p/n 6-330808-3 should be used. These contribute far less stray reactance than molded socket assemblies.

An evaluation board is available from Analog Devices for a nominal charge.

# Typical Performance ( $R_L = 100\ \Omega$ ; $A_V = +2$ , unless otherwise noted) — AD9622

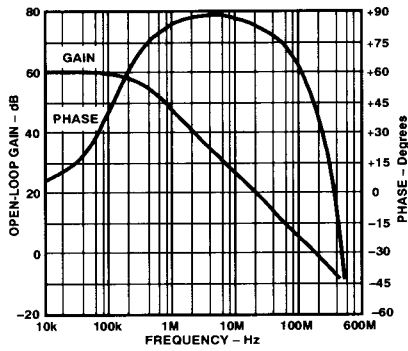


Figure 3. Open-Loop Gain and Phase

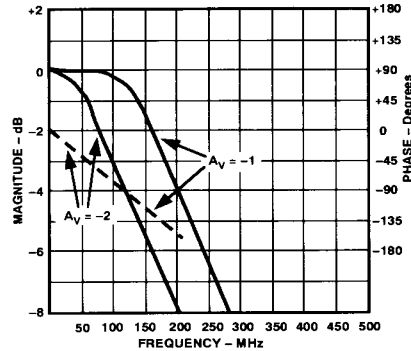


Figure 4. Inverting Frequency Response

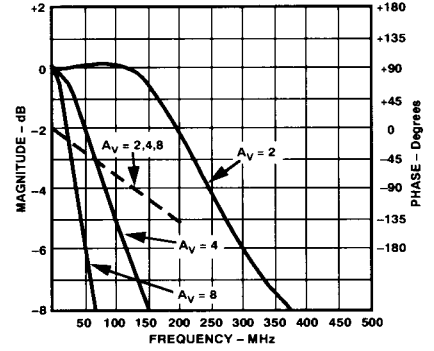


Figure 5. Noninverting Frequency Response

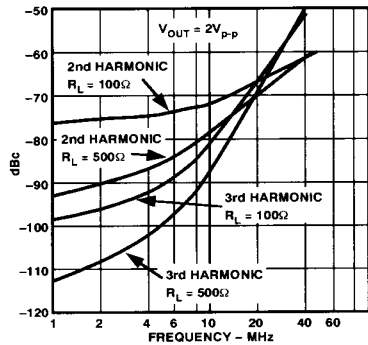


Figure 6. Harmonic Distortion vs. Frequency

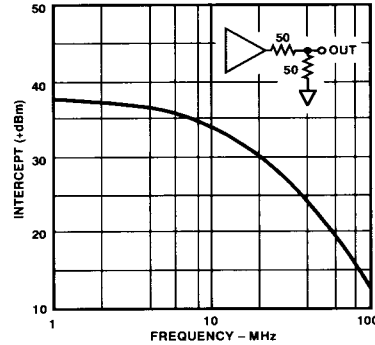


Figure 7. Third Order Intercept

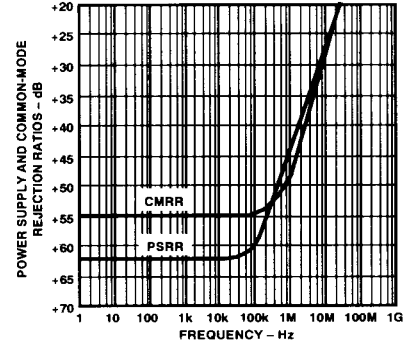


Figure 8. CMRR and PSRR vs. Frequency

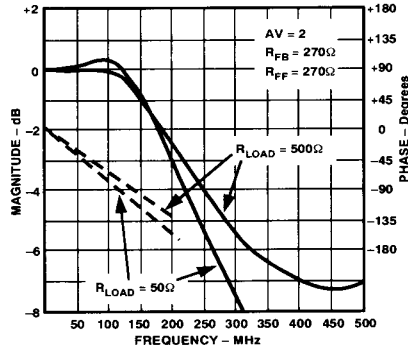


Figure 9. Frequency Response vs.  $R_{LOAD}$

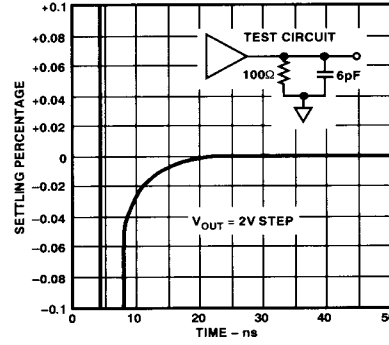


Figure 10. Short-Term Settling Time

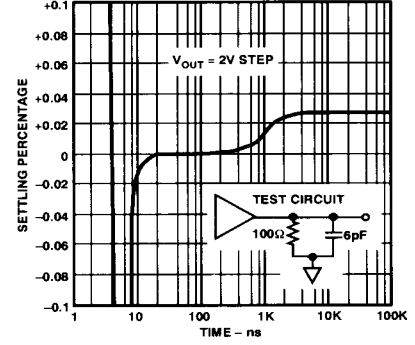


Figure 11. Long-Term Settling Time

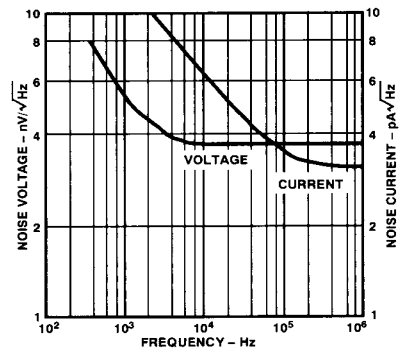


Figure 12. Input Spectral Noise Density

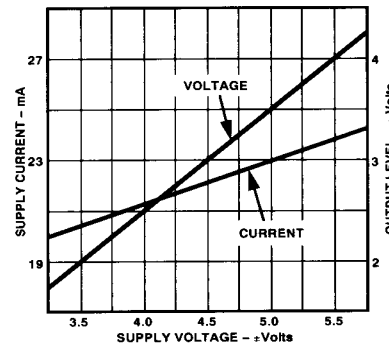


Figure 13. Output Level and Supply Current vs. Supply Voltage

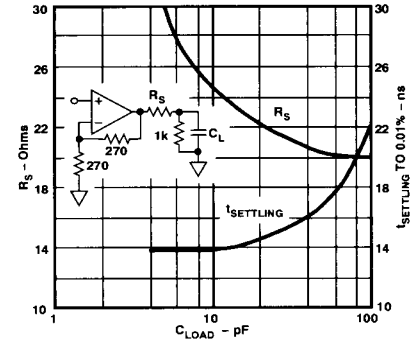
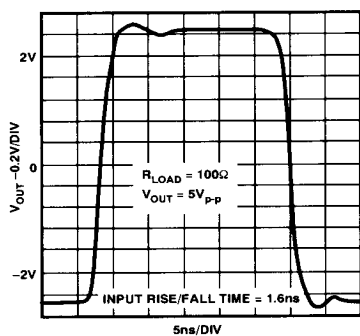
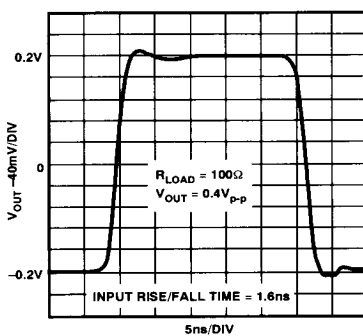


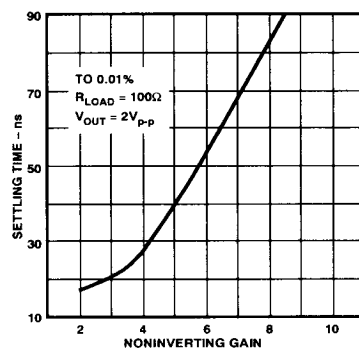
Figure 14. Settling Time vs. Capacitive Load



**Figure 15. Large Signal Pulse Response**



**Figure 16. Small Signal Pulse Response**

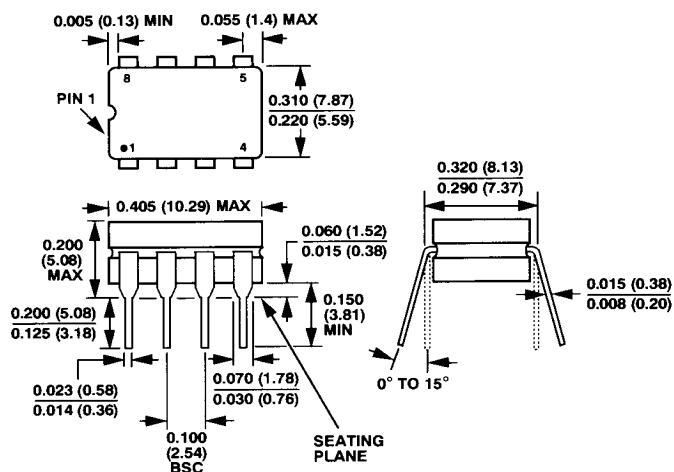


**Figure 17. Settling Time vs. Noninverting Gain**

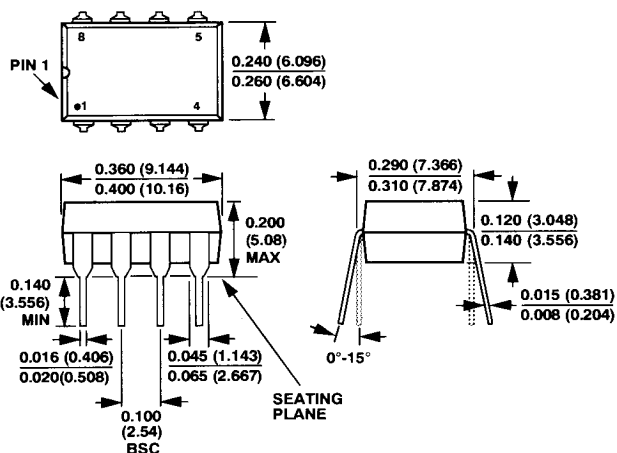
## MECHANICAL INFORMATION

Dimensions in inches and (mm)

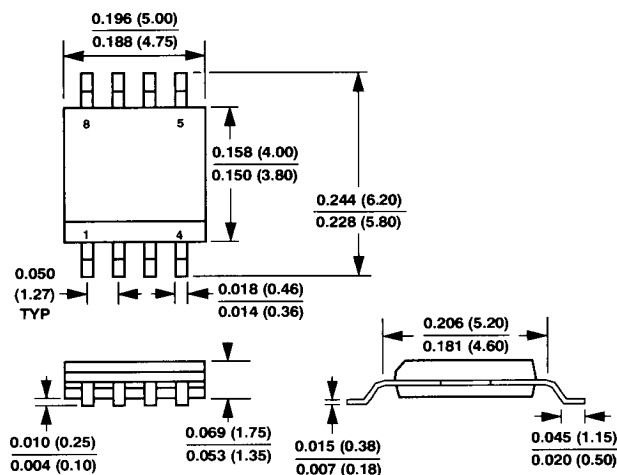
### Cerdip (Suffix Q)



### Plastic DIP (Suffix N)



### Plastic SOIC (Suffix R)



034154 ✓ R